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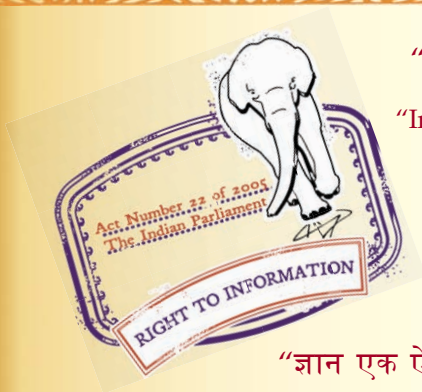
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IS 10138 (2010): Macroscopic Methods For Determination Of Non-Metallic Inclusion Content In Wrought Steels [MTD 22: Metallography and Heat Treatment]



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पिटवाँ इस्पातों में अधात्वीय अन्तर्वेशन अंश ज्ञात करने
की स्थूलदर्शी पद्धति
(दूसरा पुनरीक्षण)

Indian Standard
**MACROSCOPIC METHODS FOR DETERMINATION
OF NON-METALLIC INCLUSION CONTENT
IN WROUGHT STEELS**
(*Second Revision*)

ICS 77.040.99; 77.080.20

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BUREAU OF INDIAN STANDARDS
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FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Metallography and Heat Treatment Sectional Committee had been approved by the Metallurgical Engineering Division Council

This standard was issued in three parts, Part 1 in 1982 and subsequently revised in 1992, Part 2 and Part 3 in 1983 covering blue fracture, step machined and magnetic particle inspection method, respectively for macroscopic determination of non-metallic inclusions in wrought steels. The Committee decided to revise this standard by merging following three parts to have a single standard:

Part 1 Blue fracture test method

Part 2 Step machined method

Part 3 Magnetic particle inspection method

IS 10138 (Part 1) : 1992, IS 10138 (Part 2) : 1983 and IS 10138 (Part 3) : 1983 shall stand withdrawn after publication of this standard.

This standard has been formulated to provide methods for evaluating and expressing the size and distribution of non-metallic inclusions in wrought steel products by macroscopic methods. The parameters characterizing the non-metallic inclusions shall be their total number and their length or thickness. No distinction is made in the standard between the type of inclusions.

In reporting the results of test or analysis made in accordance with this standard, if the final value, observed or calculated expressing the results of the test or analysis, is to be rounded off it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

MACROSCOPIC METHODS FOR DETERMINATION OF NON-METALLIC INCLUSION CONTENT IN WROUGHT STEELS (*Second Revision*)

1 SCOPE

1.1 This standard describes the macroscopic methods used for assessing the content of non-metallic inclusions in wrought steel products.

1.2 Macroscopic methods are those dealing with non-metallic inclusions visible to the naked eye or with the aid of a magnifying glass with a magnification of not more than 10 ×. Only inclusions equal to or greater than 1 mm long are taken into consideration.

1.3 The methods applied and defined in this standard are:

- a) Blue fracture test method;
- b) Step machined test method; and
- c) Magnetic particle inspection method.

2 REFERENCE

The following standard contains provision which through reference in this text, constitutes provision of this standard. At the time of publication, the edition was valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

<i>IS No.</i>	<i>Title</i>
3703 : 2004	Code of practice for magnetic particle flaw detection (<i>second revision</i>)

3 GENERAL

3.1 Characteristics of Non-metallic Inclusions

Non-metallic inclusions, shown by the macroscopic methods given in **4**, **5** and **6** appear as stringers.

The parameters characterizing non-metallic inclusions shall be their total number and their length or thickness. No distinction is made concerning the type of inclusion.

3.2 Sampling

It should be noted that the shape of the inclusion as well as the number of inclusions and their distribution depend on the grade of steel, the method of production,

the conditions of killing, the shape of the ingot and the rolling reduction. These various factors should be taken into consideration when selecting the sample.

For these reasons it is not possible to formulate a universal method of sampling and accordingly general rules are given in the case of each method.

4 BLUE FRACTURE TEST METHOD

4.1 Terminology

For the purpose of this standard, the following definition shall apply.

4.1.1 Blue Fracture — The surface of a fracture which has been heated to the blue brittleness tempering range to produce a blue colour on the entire cross-section of the specimen.

4.2 Principle

The blue fracture test method consists in determining the total number and distribution of non-metallic inclusions visible on the surface of a fracture which has undergone blue tempering. This fracture is in the longitudinal direction of the product and the inclusions normally appear as white stringers.

4.3 Field of Application

The blue fracture test method is applicable to forged or rolled products and can be used for a wide range of products. In general, the test is carried out on semi-finished products.

4.4 Sampling and Preparation of Test Piece

4.4.1 Number of samples to be taken for testing for a particular cast/lot shall be subject to agreement between the supplier and the purchaser. In general five samples taken from each cast/lot shall be considered sufficient to assess the quality of steel.

4.4.2 Test Piece

4.4.2.1 The test piece shall consist of a slice the thickness (for example, between 10 and 20 mm) of which depends on the dimensions of the product, the slice thickness being measured parallel to the

longitudinal direction, and the slice being taken by hot or cold sawing or by flame cutting. The thickness shall be such that the slice can be easily fractured after cutting a notch. The thickness of the slice below the notch is recommended as 10-15 mm, the report should clearly mention the sample size, that is fractured area.

4.4.2.2 When flame cutting is used, care shall be taken to ensure that the fracture takes place outside the heat-affected zone.

4.4.2.3 The number and position of the test pieces shall be the subject of agreement between the purchaser and the manufacturer. For samples of smaller cross-section (up to about 100 mm² square/round) a single notch transverse to the direction of rolling shall be cut as shown in Fig. 1A. In case the cross-section of material is large (above 100 mm²) test piece selection may be done as given in Fig. 1B or Fig. 1C for square/rectangular and round product respectively.

4.4.2.4 Two notches perpendicular to each other shall be cut on the test piece as shown in Fig. 1B or Fig. 1C and the fractured surfaces examined in two directions. The depth of the notch shall be not more than one-third of sample thickness. The notch shall be sufficiently sharp so that the sample can be fractured without much plastic deformation.

4.5 Test Procedure

4.5.1 After undergoing normalizing treatment if necessary, the test piece shall be either heated in air so that at the moment of starting the test, the metal is at the blue brittleness temperature (300°C to 400°C) or fractured at the ambient temperature and the two pieces subsequently heated to blue colour on the fractured surfaces.

4.5.2 In certain cases, which may be subject to agreement between the parties concerned, the test piece may be hardened, possibly followed by tempering.

4.5.3 The fracture produced on one of the two broken parts of the test piece shall be examined with the naked eye or with the help of a magnifying glass with a magnification less than or equal to 10 X.

4.5.4 In case of difficulty in fracturing a specimen, prior quenching treatment may be given.

4.6 Method of Estimation

4.6.1 The examination may be carried out qualitatively or by special agreement between the parties concerned, quantitatively.

4.6.2 Qualitative Examination

Qualitative examination shall be carried out by comparison with the series of ten reference diagrams

included in Fig. 2. When interpreting in conjunction with Fig. 2, account shall be taken of the positions of the inclusions within the section, separately for outer (Y) and centre zone (C) and the results may be presented in a table as given below:

Sample No.	The Worst Rating of Each Sample as per Fig. 2	
	Outer Zone (Y) as defined in Fig. 1A	Centre Zone (C)
1	0	2
2	1	3
3	2	0
4	3	1
5	4	3

4.6.3 Quantitative Examination

Quantitative examination shall be carried out by counting inclusions and using one (or both) of the following parameters of the inclusions:

- Length, and
- Thickness.

The distribution of the inclusions according to the parameter(s) chosen shall be established according to Tables 1 and 2.

Table 1 Inclusion Distribution Based on Length

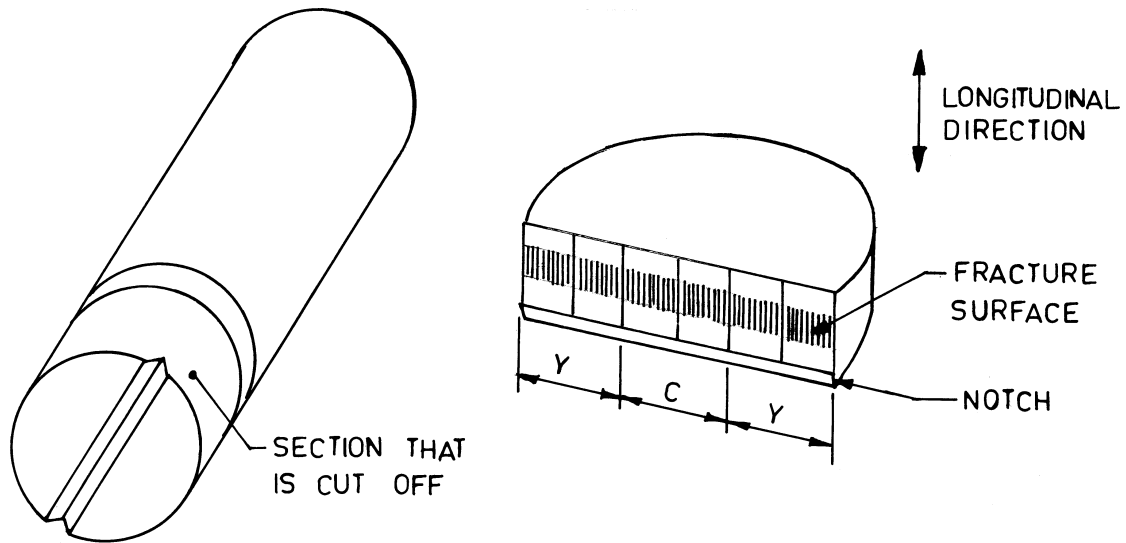
SI No.	Symbol	Length, <i>l</i> mm
(1)	(2)	(3)
i)	L_0	No macroscopic inclusion
ii)	L_1	$1.5 \leq l \leq 2.5$
iii)	L_2	$2.5 < l \leq 5.0$
iv)	L_3	$5.0 < l \leq 10$
v)	L_4	$10.0 < l$

Table 2 Inclusion Distribution Based on Thickness

SI No.	Symbol	Thickness, <i>T</i> mm
(1)	(2)	(3)
i)	T_0	No macroscopic inclusion
ii)	T_1	$0.1 \leq T \leq 0.25$
iii)	T_2	$0.25 < T \leq 0.50$
iv)	T_3	$0.50 < T \leq 1.00$
v)	T_4	$1.0 < T$

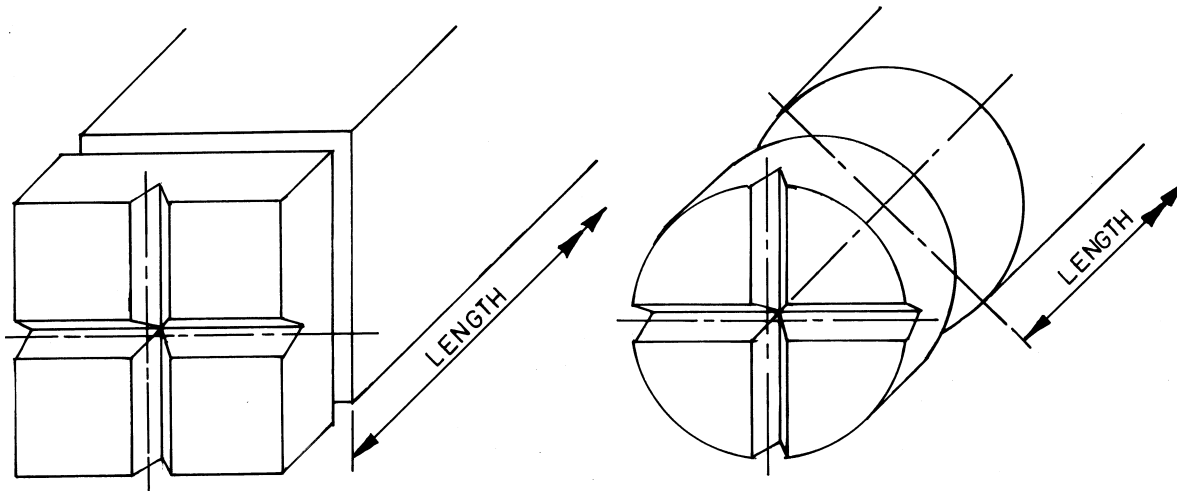
4.6.4 The acceptance limits shall be the subject of mutual agreement between the purchaser and the manufacturer.

4.6.5 Comparative tests shall be carried out on the products which have undergone similar manufacturing process and similar size reduction by hot working.



Y = OUTER ZONE
C = CENTRE ZONE

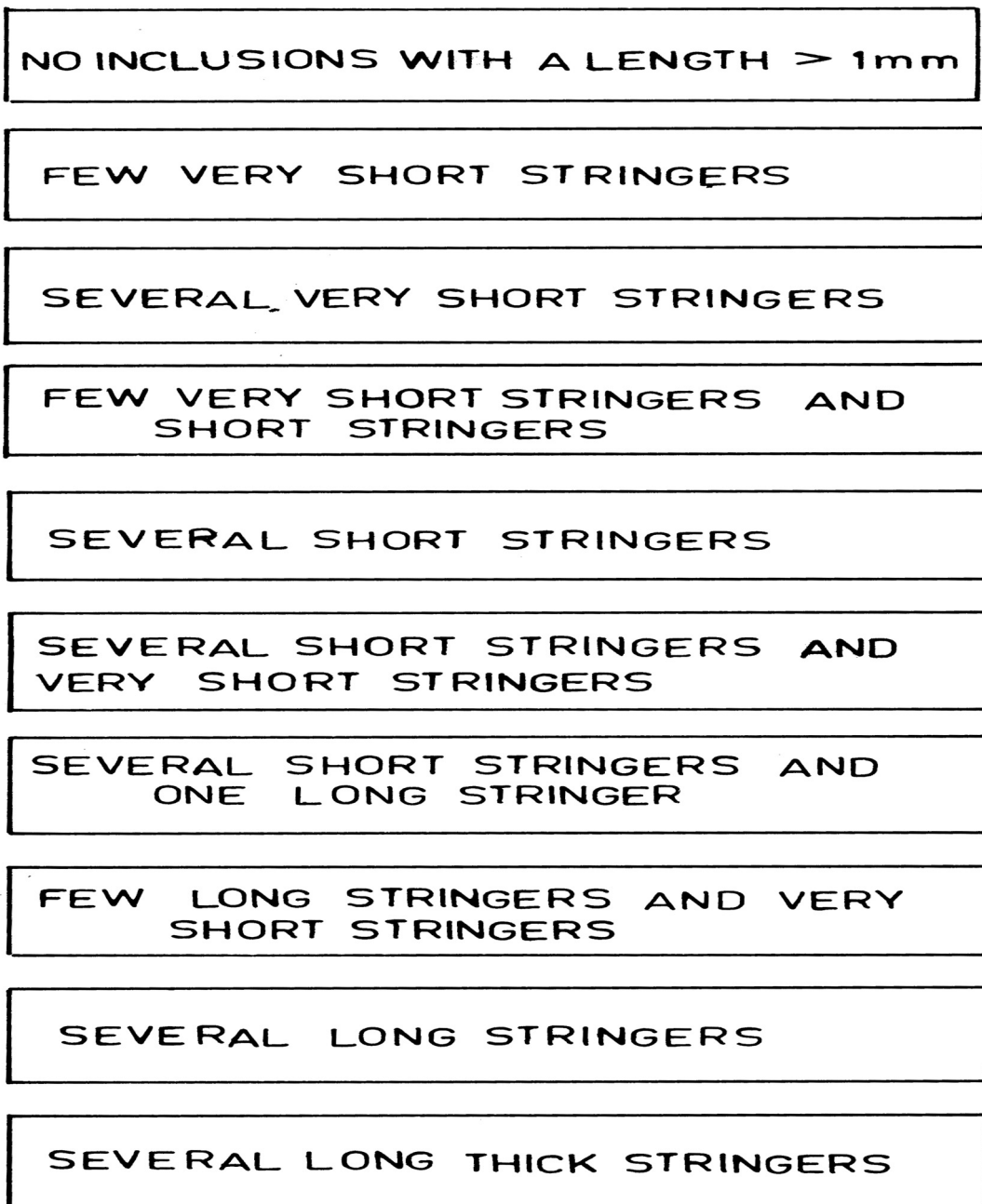
1A Cross-section (up to 100 mm²) of Square/Round with a Single Notch



1B Cross-section (up to 100 mm²) of Square/
Rectangular with Two Notches

1C Cross-section (up to 100 mm²)
Round with Two Notches

FIG. 1 TEST PIECES WITH NOTCHES



Explanation of terms

Very short : 1 to 2.5 mm Few : ≤ 3
stringers
Short stringers : > 2.5 mm, Several : > 3
 ≤ 5 mm
Long stringers : > 5 mm Thick : > 0.5 mm

FIG. 2 STANDARD DIAGRAM FOR THE BLUE FRACTURE TEST METHOD

5 STEP MACHINED TEST METHOD

5.1 Principle

The step machined test method consists of determining the total number and the distribution of non-metallic inclusions revealed by machining and visible on the longitudinal surfaces of a cylindrical stepped test piece.

5.2 Field of Application

The test is applicable to rolled and forged products of simple shape. The test piece is generally machined from samples of bars or billets.

5.3 Sampling and Preparation of Test Piece

5.3.1 Sampling

The number of test pieces and their location shall be subject to agreement between the parties concerned.

5.3.2 Test Piece

5.3.2.1 According to the type of product and the purposes of the examination, the cylindrical test piece shall contain one or more concentric steps. Products with non-circular sections may be forged into the round bars before hand.

5.3.2.2 The test piece in common usage comprises three steps the dimensions of which are as given in Table 3 (see Fig. 3).

Table 3 Dimensions of Steps of Test Piece

(Clauses 5.3.2.2 and 5.3.2.3)

Sl No.	Step	Diameter mm	Length mm
(1)	(2)	(3)	(4)
i)	1	0.90 D	60
ii)	2	0.75 D	72
iii)	3	0.60 D	90

NOTE — D = diameter or side of the product.

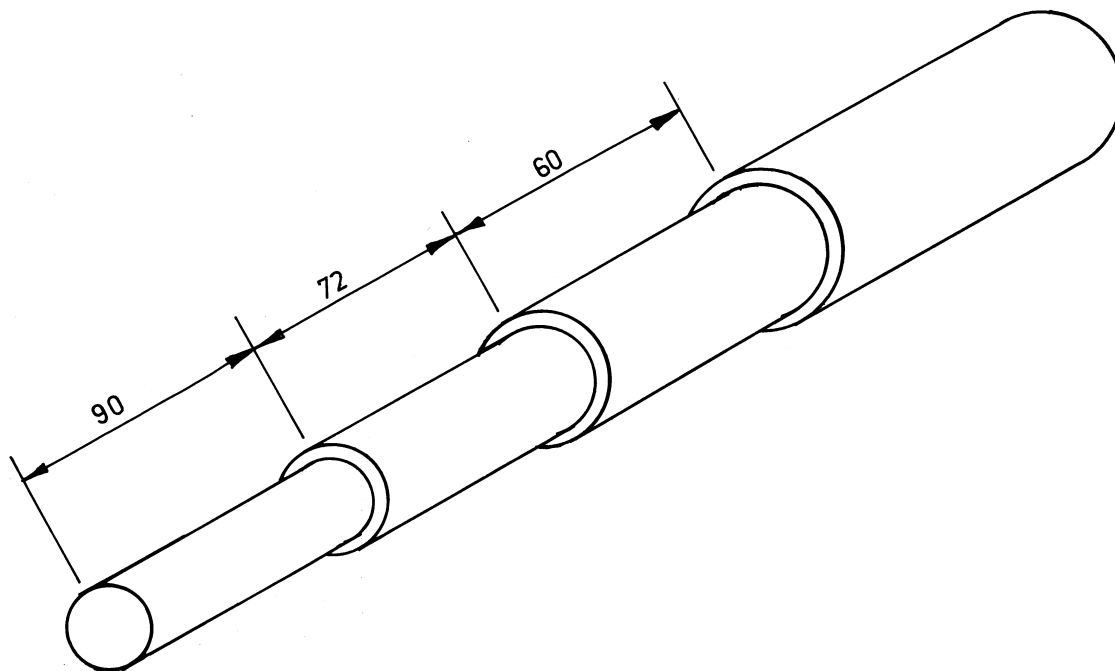
5.3.2.3 In the test piece dimensioned as in Table 3, the lengths of the steps are such that the surface area of each step is identical. Other dimensions of steps may be used subject to agreement between the parties concerned.

5.3.2.4 The test piece shall be carefully centered. Where it is necessary to have a greater area for examination, each step shall be machined successively along the whole length of the test piece, after establishing the number of inclusions for each step.

5.3.2.5 The test piece shall be turned so that the depth of the last cut is less than 0.2 mm. The machined surface shall be smooth and shall not show a relief which is too pronounced.

5.4 Test Procedure

5.4.1 The test piece shall be examined with the naked eye or with the help of a magnifying glass (maximum magnification 10 X).



All dimensions in millimetres.

FIG. 3 STEP MACHINED TEST PIECE

5.4.2 To facilitate examination, the test piece may be retained in the lathe, so that it may be rotated. A reference line should be marked along the entire length of the test piece. Similarly, the inclusions counted should, also be marked (for example by putting a circle round them) to avoid double counting.

5.4.3 Special precautions shall be taken when examining, so that only lines relating to non-metallic inclusions are taken into consideration, as machining of the test piece surface may also reveal macroscopic irregularities such as cracks, pipe seams, metallic inclusions, etc.

5.5 Estimation of Test Results

5.5.1 For each step, the number of inclusions and their lengths shall be determined.

5.5.2 The distribution of inclusions in terms of their size may be obtained by using the classification given in Table 4.

**Table 4 Distribution of Non-metallic Inclusions
Based on Length**
(Clauses 5.5.2, 5.5.5 and 6.5)

Sl No.	Length of the Inclusions mm	Weight Factor	No. of Indications
(1)	(2)	(3)	(4)
i)	Over 1 to 2.5	1	N_1
ii)	Over 2.5 to 5	2	N_2
iii)	Over 5 to 10	4	N_3
iv)	Over 10 to 20	8	N_4
v)	Above 20	16	N_5

5.5.3 Test results may be expressed in terms of frequency and severity value.

5.5.4 Frequency may be expressed as the total number of indications in a given area. A common area of 100 cm² may be taken for denoting the frequency.

5.5.5 Severity is the weighted value of the indications which may be taken as given in Table 4.

5.5.6 The severity value is calculated by multiplying the number of indications of a given length with weight factor and adding these results and is expressed as the weighted value per 100 cm². Thus for a specimen of total area (A cm²), the severity is expressed as:

$$= \frac{(N_1 \times 1 + N_2 \times 2 + N_3 \times 4 + N_4 \times 8 + N_5 \times 16)}{A} \times 100$$

6 MAGNETIC PARTICLE INSPECTION METHOD

6.1 Principle

The test consists in examining the machined surface

of a test piece or product submitted to a magnetic field and coated with a liquid containing a ferromagnetic powder suspension. Magnetic particle inspection may be carried out by the dry method, by special agreement between the parties concerned.

6.1.1 Non-metallic inclusion causes a distortion in the induced magnetic field. This distortion attracts and holds the ferromagnetic powder, giving visible indication.

6.1.2 It should be noted that other irregularities in the metal such as cracks, blowholes and shrinkage cracks, also give an indication under magnetic particle inspection. Precautions should be taken to ensure that the readings obtained correspond properly to the non-metallic inclusions by means of a supplementary examination such as a dye penetrant test.

6.2 Field of Application

6.2.1 Magnetic particle inspection is applicable to only ferromagnetic steels. It is generally used for products such as slabs, bars, billets and tube rounds.

6.3 Sampling

6.3.1 The methods of sampling, the number of samples and their location shall be subject to agreement between the parties concerned. Normally the surface which is to be examined shall be in the longitudinal direction of the product. The type of the test piece used may vary according to the shape of the product and depending upon the examination carried out.

6.3.2 Preparation of the Test Piece

6.3.2.1 In the case of bars, billets and rounds, the following examination surfaces may be chosen:

- Surface of the product after a fine grinding;
- An axial section of the product;
- A step machined test piece shall be prepared as stipulated in 4; and
- Cylindrical test pieces obtained by machining or forging and taken from a quarter of the section of the product, machining being carried out so that the axis of the product is included on the surface of the test piece (see Fig. 4 and Fig. 5).

6.3.2.2 Preparation of the surface to be examined or of the test piece shall be carried out by fine grinding, perpendicular to the direction of the rolling in order to be able to distinguish any machining marks and to avoid tearing out the whole of the inclusions.

6.3.2.3 Care should be taken while preparing the surface to ensure that the smaller inclusions are not torn out.

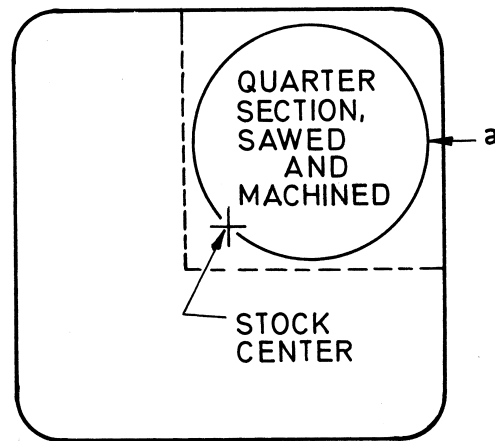


FIG. 4 QUARTER SECTION SPECIMEN FROM SQUARE SECTION FOR MAGNETIC PARTICLE TEST, MACHINE ONLY

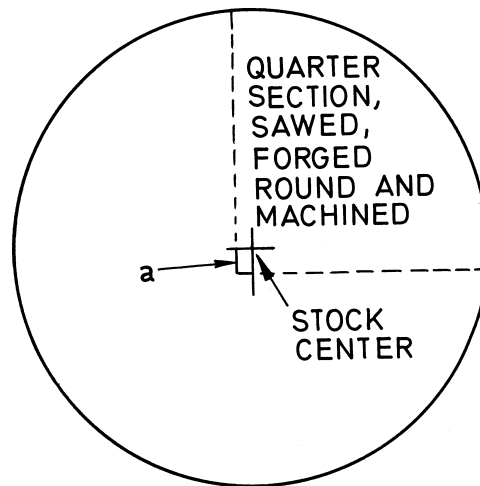


FIG. 5 QUARTER SECTION SPECIMEN FROM ROUND SECTION FOR MAGNETIC PARTICLE TEST, FORGING AND MACHINING

6.3.2.4 The ends of the test piece should also be machined to facilitate magnetization.

6.4 Magnetization

The test piece shall be magnetized by the current flow method by passing a current directly through the test piece. The type of current and the current intensity shall be subject to special agreement between the parties. In general a current intensity of 200 A/cm of the test piece diameter is found to be adequate.

6.4.1 Reference should also be made to IS 3703 for details of magnetization techniques.

6.4.2 Before the test, the surface shall be carefully cleaned with a solvent so that no trace of grease or any contamination remains.

6.4.3 The magnetizing current shall then be passed and the indicator fluid immediately poured over the entire surface, the current being maintained.

6.4.4 The surface shall then be carefully dried with an air jet. For drying a volatile solvent may also be used. The current being maintained, the solvent shall be poured over the surface and drying shall be carried out by means of an air jet. In this case, it is recommended that any excess solvent be collected in order to avoid contamination of the indicator fluid.

6.4.5 In case of high hardness steels (50 HRC or 515 HV) application of the indicator shall be made after magnetization of the sample.

6.4.6 It is recommended that the apparatus should be checked by means of control samples, to ensure that the control is completely sensitive.

6.5 Estimation of Test Results

The distribution of inclusions in terms of their size may be obtained according to the same classification as given in 5.5 (see also 5.5.1, 5.5.2, 5.5.3 5.5.4, 5.5.5, 5.5.6 and Table 4).

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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